2P5-6

Experimental Study of Ultrasound Imaging Employing Compressive Sensing

圧縮センシング技術を用いた超音波イメージングの実験的検討

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1. Introduction

Compressive sensing (CS)[(1,2] is a novel sensing method and has attracted attention to many fields. Assuming sparsity of target, CS makes it possible to fast imaging while maintaining image quality. In medical field, CS has been used for magnetic resonance imaging (MRI) to reconstruct images from significantly fewer measurements. Recently, CS for ultrasound imaging has been introduced in ultrasound imaging for fast imaging, reducing elements, and improving quality. In this study, the optimized process of compressive sensing for ultrasound imaging is investigated with various sampling times.

2. Method

To obtain RF signals for compressive sensing, A soft tissue-mimicking phantom (US-2 multi-purpose phantom N-365, Kyoto Kagaku) including string wires was used in this experiment. Each diameter of string wires is 0.1 mm. **Figure 1** describes the experimental setup and arrangement of targets. Ultrasonic pulses were emitted and echo signals were obtained using a pulser/receiver (DPR300, JSR Ultrasonics), and a single transducer (V312-SU, Olympus Inc.), which center frequency is 5 MHz, focal distance is 25.4mm, and diameter is 6 mm. The single transducer was moved by an automatic positioning stage during the scan. The scanning pitch was 0.5 mm and 91 RF signals were obtained.

In compressive sensing process using the Lasso algorithm[(3], the optimization objective for Lasso is expressed as

$$\min_{x} \left\{ \frac{1}{2n} \|\boldsymbol{y} - A\boldsymbol{x}\|_2^2 + \lambda \|x\|_1 \right\} \quad (1)$$

where n is the number of samples, $y \in \mathbb{C}^m$ is the measurement vector, $A \in \mathbb{C}^{m\times n}$ is the measurement matrix, $x \in \mathbb{C}^{n\times 1}$ is a sparse vector, m is the number of observations. Computing x by solving eq. (1), compressive signal is obtained.

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In this study, compressive sensing process is adopted in various processes, and obtained B-mode images are compared. As shown in **Fig. 2**, radio frequency (RF) signals, envelope signals, and log-compressed signals are used as the measurement vector, respectively. In addition, to reduce calculation time, decimation process is employed to envelope signals. When compressive sensing is employed after decimation, the calculation time of compressive sensing will become shorter. The sampling time of RF signal was 0.8 nsec (1.25 GHz), and it was decreased to 8 nsec (125 MHz) and 80 nsec (12.5 MHz) in each decimation process. Each process was calculated 3 times to calculate the average of calculation time.

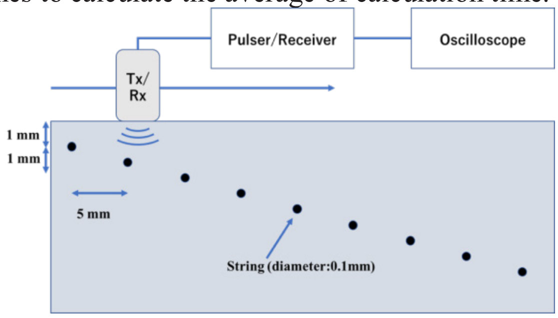


Fig. 1 Experimental setup.

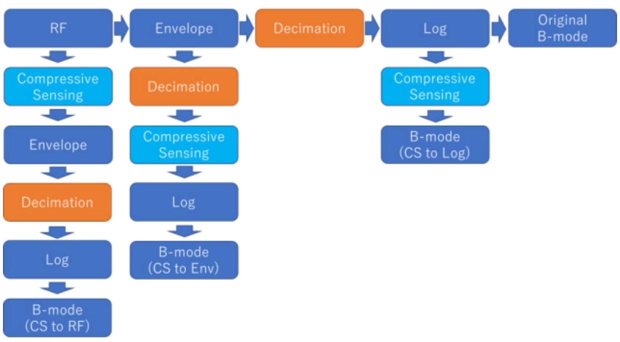
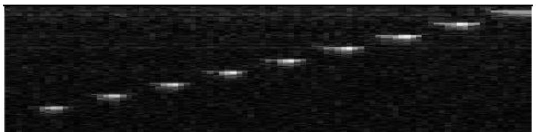


Fig. 2 Flowchart of proposed processes.

3. Results

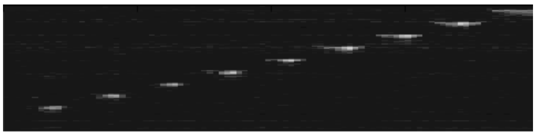
Figures 3 and 4 shows B-mode images with sampling time of 0.8, 8, and 80 nsec. Axial and lateral resolution are shown in **Figs. 5 and 6.** Each average calculation time is listed in **Table I**.



(a)

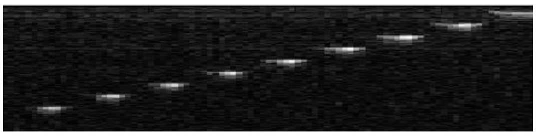
(b)

(c)



(d)

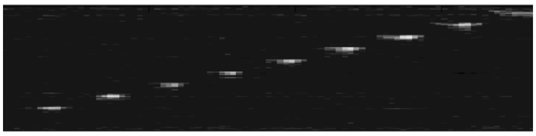
Fig. 3 B-mode images with time sampling of 0.8 nsec. (a)w/o CS, (b)CS to RF signals, (c)CS to envelope signals, and (d) CS to log-compressed signals.



(a)

(b)

(c)

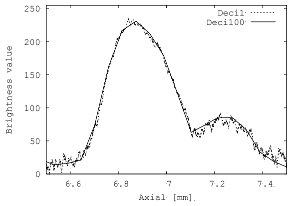


(d)

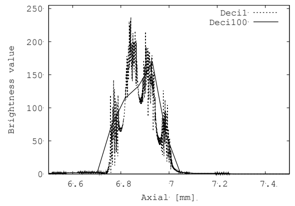
Fig. 4 B-mode images with time sampling of 80 nsec. (a)w/o CS, (b)CS to RF signals, (c)CS to envelope signals, and (d) CS to log-compressed signals.

Table I Calculation time.

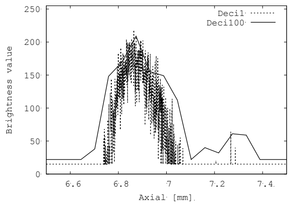
Ts after decimation [nsec]	CS to RF [sec]	CS to Env [sec]	CS to Log [sec]
0.8	501	517	708
8	510	28	31
80	506	23	24



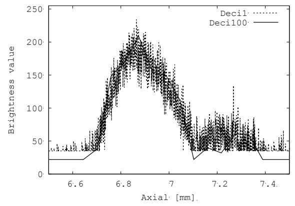
(a)



(b)

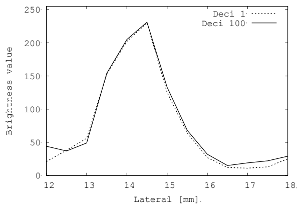


(c)

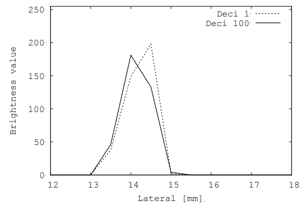


(d)

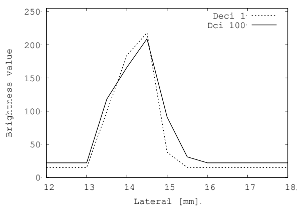
Fig. 5 Axial resolution of B-mode images with time sampling of 0.8 nsec (dash line) and 80 nsec (solid line). (a)w/o CS, (b)CS to RF signals, (c)CS to envelope signals, and (d) CS to log-compressed signals.



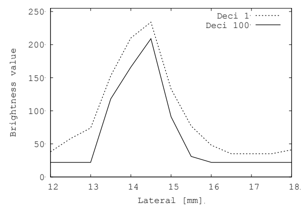
(a)



(b)



(c)



(d)

Fig. 6 Lateral resolution of B-mode images with time sampling of 0.8 nsec (dash line) and 80 nsec (solid line). (a)w/o CS, (b)CS to RF signals, (c)CS to envelope signals, and (d) CS to log-compressed signals.

4. Conclusion

In this study, CS for ultrasound images are investigated with various processes and time sampling. Fine B-mode images with CS-to-RF and CS-to-Env processes were obtained with lower sampling rate. Further investigation of degradation in axial resolution due to down-sampling is needed.

References

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3. R. Tibshirani: J. R. Statist. Soc. B **58** (1996) 267.